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Effect of Soil Water Content and a Growing Season Straw Mulch on Grain Sorghum

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ABSTRACT

The results of previous studies with a straw mulch in place during fallow and the growing season of grain sorghum (*Sorghum bicolor* L. 'Moench') suggested that having the mulch in place during the growing season increased the use efficiency of growing season rainfall. The objective of this study was to evaluate the contribution of a growing season straw mulch to growth, yield, grain quality, water use, and water-use efficiency of grain sorghum. Before sorghum was planted in 1977, 1978, and 1979, areas of Pullman clay loam (fine, mixed, thermic Torrertic Paleustolls) were irrigated twice, irrigated once, or not irrigated to simulate high, medium, and low levels of water storage in soil during fallow. After sorghum emergence, wheat (*Triticum aestivum* L.) straw was placed on the surface at rates of 0 (check), 2, 4, or 8 metric tons/ha. Differences in sorghum response to the high and medium water levels were slight because the second irrigation resulted in relatively little additional water storage in the slowly permeable soil even though the soil was not filled to capacity. Sorghum with the high and medium water levels grew taller, yielded more, and used water more efficiently than sorghum with the low water level at planting. In general, sorghum responded more to soil water content at planting than to mulch rate during the growing season. When significant responses to mulch rate were obtained, they resulted mainly from mulch on the low water level plots. For the 3 years, the growing season mulch at 8 metric tons/ha increased water-use efficiency 19% over the no-mulch treatment, which was less than expected, based on earlier experiments and observations. Apparently, shading from the plant canopy largely substituted for the beneficial effect of a mulch during the growing season. When a mulch is present during both the fallow and the growing seasons, a major effect with respect to water conservation and crops production, therefore, is to enhance water storage in soil during fallow.

***Additional Index Words:* *Sorghum bicolor*, water-use efficiency, sorghum growth, sorghum grain yield.**

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BY COVERING SOIL with plastic films, Griffin et al. (1966), Peters (1960), and Willis et al. (1963) obtained yields of grain crops that were as high or higher than those from uncovered soil treatments. The covered treatments resulted in considerably less water use and, therefore, higher water-use efficiency. Plastic films, however, inhibit water entry into soil and are not practical or economical for widespread use for most grain crops.

Other materials that have been used as soil covers or mulches to decrease water use by crops or to increase water-use efficiency include gravel, wood chips, petroleum sprays, and so forth. These materials decreased evaporative losses of soil water but again were not practical for use with grain crops. Crop residues, however, generally are readily available and have increased soil water contents under field conditions by enhancing infiltration or decreasing evaporation (Duley, 1940; Greb et al., 1967, 1970; Mannering and Meyer, 1963; Borst and Woodburn, 1942; Unger, 1978; Unger et al. 1971; Unger and Wiese, 1979).

In the studies by Unger (1978) and Unger and Wiese (1979), wheat (*Triticum aestivum* L.) straw was maintained on the soil during fallow from wheat harvest until grain sorghum (*Sorghum bicolor* L. 'Moench') planting and during the sorghum growing season either as a mulch or in a no-tillage cropping system. Water storage in soil from precipitation increased with increasing surface residue rates, which increased grain yields of sorghum planted after fallow. The yield response to stored soil water in these studies was greater than where limited amounts of residue were on the surface (Jones and Hauser, 1975), suggesting that the presence of surface residues during the growing season provided an additional benefit by increasing the use efficiency of growing season rainfall. The objective of this study was to evaluate the contribution of a growing season straw mulch to grain sorghum growth, yield, grain quality, water use, and water-use efficiency.

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MATERIALS AND METHODS

The study was conducted from 1977 to 1979 on field plots of Pullman clay loam (fine, mixed, thermic Torrertic Paleustolls) with 0.5% slope at Bushland, Tex. Winter wheat growing after fallow on the research area was destroyed by plowing in Jan. 1977. The research plots were then established on two areas with dryland sunflower (*Helianthus annuus* L.) grown in a 2-year rotation with sorghum. Each spring, three soil water levels designated high, medium, and low were established by irrigating twice, irrigating once, or not irrigating the areas where the sorghum would be planted. These imposed soil water levels simulated different soil water contents that could have resulted during a fallow period. The mulch rate plots were then established on the different water level areas for growing sorghum. Sorghum planting dates were 23 May 1977, 15 June 1978, and 13 June 1979. Sorghum hybrid C42y+ was planted with unit planters in single rows on 1-m spaced low ridges at a rate to obtain about 96,000 plants/ha.

Terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine][3] was applied before sorghum emergence at a rate of 1.7 kg/ha for growing season weed control. No fertilizer was applied because dryland crops on Pullman clay loam at Bushland have not responded to applied fertilizers (Eck and Fanning, 1962).

After sorghum emergence, wheat straw was placed on 5 by 5 m plots at rates of 0 (check), 2, 4, or 8 metric tons/ha. Straw application dates were 9 June 1977, 28 June 1978, and 28 June 1979. On 19 June 1977, wind removed the straw from the plots. The straw was replaced on 21 June and covered with plastic netting. The plastic netting was also used in 1978 and 1979. The straw mulch rates were replicated four times in a randomized block experimental design on the three water level blocks.

Soil water contents were monitored by the neutron-scattering technique at one location per plot to a 1.8-m depth at about 2-week intervals during the sorghum growing season. Rainfall was measured near the plots, and surface water flow across the plots was prevented by small dikes at the upslope border of each plot.

Plant heights were measured periodically during the growing season. After grain maturity or frost, grain and forage yield samples from 2 m of row length were harvested by hand from the two center rows of each plot. Grain yields were adjusted to 13.0% moisture. Forage samples were oven-dried at 60°C, and yields were reported on that basis.

RESULTS AND DISCUSSION

Precipitation

Total rainfall from 1 June until sorghum harvest was near the long-term average in 1977 and 1979, and above the long-term average in 1978 (Fig. 1). In each season, however, there were periods of below and above average rainfall. In 1977, rainfall was below average early in the season, considerably above average during August, and below average during September and October. Rainfall was above average in early June 1978, then below average until 19 and 20 September when a record 15.8 cm of rain fell in a 24-hour period. As in 1978, early June 1979 rainfall was above average. In 1979, however, rainfall remained near average until late August, after which little effective rainfall occurred.

Initial Soil Water Content

Because the mulch treatments were applied after sorghum emergence, the initial plant-available soil water contents within each preestablished soil water level treatment were similar (Fig. 2, ABC). The initial water contents to a 1.2-m depth for the high, medium,

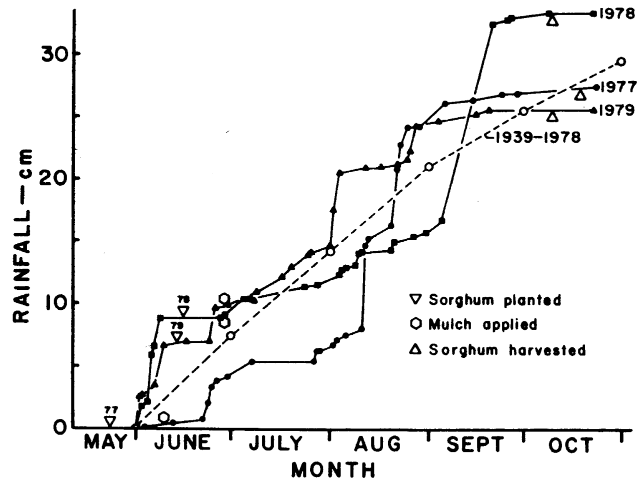


Fig. 1—Cumulative rainfall at Bushland, Tex., for 1977 to 1979 for time from near planting to harvest of grain sorghum. The long-term average is also shown.

and low water level treatments averaged 13.6, 12.4, and 9.7 cm, respectively, in 1977; 19.7, 17.9, and 12.9 cm in 1978; and 19.8, 18.7, and 12.8 cm in 1979.

In 1977, the water content in the upper 0.3 m of the low water level treatment plots was low because the water had been extracted by the winter wheat that was destroyed before establishing the plots and because of low rainfall early in the year. The relatively high water content below the surface layer resulted from water stored during the 15-month fallow period that preceded wheat planting in the fall of 1976. The higher water contents in the upper increment of the high and medium water level treatment plots resulted from irrigation to establish the water levels, but even these water contents were relatively low because the water was applied from 30 to 45 days before planting, thus allowing considerable water loss by evaporation from the surface layer.

In 1978 and 1979, above-average rainfall before planting caused the water content in the upper increment of all plots to be relatively high and similar. Deeper in the profile, the water contents reflected the different amounts applied.

Sorghum Emergence, Growth, and Tillering

Emergence was rapid and uniform in all plots each year except in 1977 in the low water level plots when only an estimated 20% of the seed germinated and produced seedlings. The poor emergence was caused by the low water content in the surface layer of these plots because no effective rainfall was received before or soon after planting.

Sorghum growth was mainly affected by soil water level and little affected by mulch rates, except in the low water level treatment plots in which plants in the no-mulch plots were always the shortest at harvest.

Sorghum plants produce tillers in response to plant populations and plant water stress. When produced early enough, the tillers produce grain-bearing panicles. In 1977, when rainfall was below average early in the growing season, most tillers were produced after the above-average rainfall in August. In the high and medium water level plots, initial plant populations were adequate so that rainfall in August resulted in

[3] This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended.

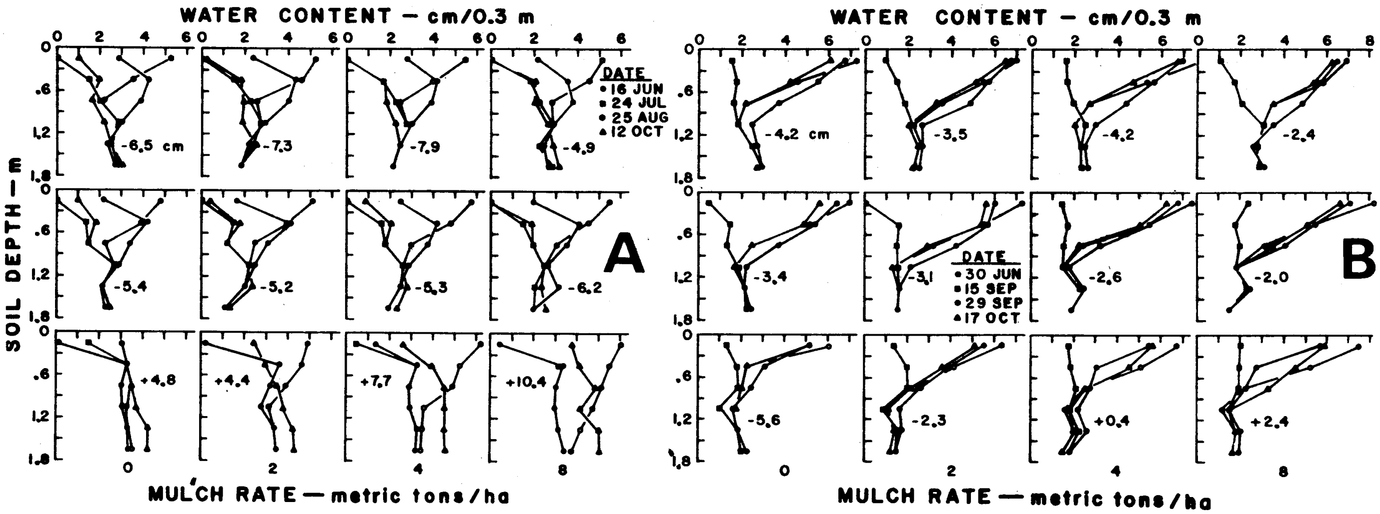
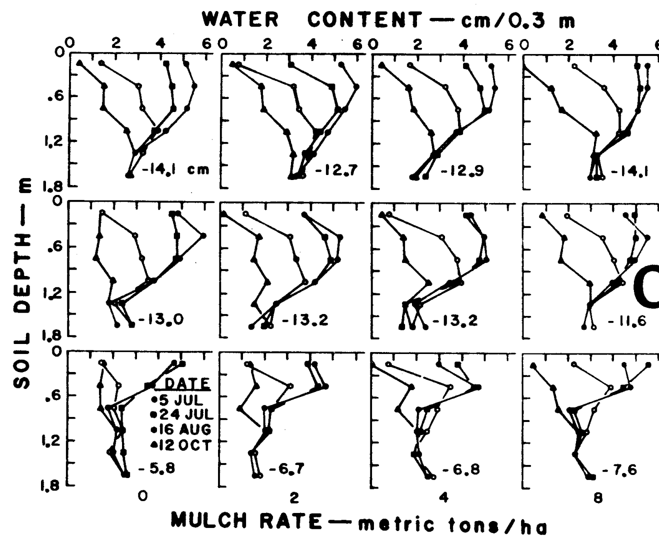


Fig. 2—Available soil water contents at planting, during the growing season, and at harvest of grain sorghum as affected by mulch rates and initial soil water levels at Bushland, Tex., (*A*) 1977, (*B*) 1978, and (*C*) 1979. Centimeter values show net change from planting to harvest to a 1.8-m depth. Upper part of figure is for high, middle for medium, and lower for low water level treatments.



the formation of relatively few additional panicles per plant than the initial plant populations (about 96,000/ha) (Table 1). The number of panicles in the low water level plots was significantly lower than in the other plots and increased as mulch rates increased. Based on an estimated plant population of 20,000/ha (about 20% of that in the other water level treatment plots), the number of grain-bearing panicles per plant ranged from about two with no mulch to six and one-half with 8 metric tons/ha of mulch. In 1978 and 1979, there were fewer panicles on the low water level plots than on other plots, but mulch rate had no significant effect.

Sorghum Yield and Quality

Grain yields with the high and medium water level treatments were similar each year, and these were significantly higher than those with the low water level treatment (Table 1). In 1977 and 1979, grain yields were significantly lower in the no-mulch plots than in the mulched plots. Lack of grain yield response to the different mulch levels was surprising because previous studies showed a greater response to soil water content at planting with a mulch present (Unger, 1978) than without a mulch (Jones and Hauser, 1975). Differences in growing season rainfall distribution may have been involved. In 1977, most rain after planting fell in a 14-day period in August, whereas in 1978, most rain after planting fell in a 24-hour period in September. Consequently, the soil was rather uniformly wetted, regardless of mulch rate, and subsequent effects of mulch rates on evaporation were minimal because the plant canopies were well established at this time. Maranville and Clark (1979) reported similar results in Nebraska wherein total dry matter yield of irrigated sorghum was not significantly affected by mulch rates. These results suggested that when water is not limiting or is applied in relatively large amounts at several times during the growing season, as in this study in 1977 and 1978, the effect of a growing season mulch is minimized. In 1979, more frequent and near-average rainfall during July and August resulted in slower depletion of soil water with the higher mulch rates (Fig. 2C), but below-average rainfall in September minimized the potential yield advantage that plants in the high mulch rate treatment plots may have had over those in the low mulch rate treatment plots.

Forage yields (excluding grain) (i) increased significantly as mulch rates increased in 1977, (ii) were significantly higher with 8 metric tons/ha of mulch than with other treatments in 1978, and (iii) were not significantly affected by mulch rate in 1979. In 1977 and 1979, forage yields were significantly higher with the high and medium water level treatments than with the low water level treatment. The plant population was low on the low water level treatment plots in 1977. Forage yield with the low water level treatment averaged more than double the grain yield for this treatment. For the other water level treatments, forage yields exceeded grain yields by only 18%. The high forage yields relative to grain yields for the low water level treatments indicate that plants had largely depleted the readily available soil water before grain filling occurred. This is illustrated in Fig. 2C for 1979, which shows greater depletion on the low water level treatment plots than on other plots on the same dates In 1977, plants in the low water level plots tillered more than those in other plots, which resulted in high forage yields. The tillers, however, produced relatively little grain because their panicles were produced relatively late in the growing season and were smaller than those produced earlier in the season. Water below the 0.3-m depth was not effectively used by sorghum in the low water level treatment plots in 1977 (Fig. 2A).

Mulch rates had no significant effect on grain test weight, but water level treatments significantly affected test weights in 1977 and 1979 (Table 1). The test weight response to water level, however, was variable, with test weights being highest in 1977 when August rainfall provided for good grain filling and lowest in 1979 when lack of late season rainfall caused severe plant water stress.

Grain weight (mg/grain) was significantly affected by mulch rate only in 1979, when increasing mulch rates resulted in decreasing grain weights (Table 1). The mulch rate by water level treatment interaction was also statistically significant. The significant interaction resulted from grain weights being highest and lowest with 0 and 8 metric tons/ha of mulch, respectively, on the low water level treatment plots. These

Table 1—Effect of mulch rate and initial soil water level on grain sorghum panicles, yield, grain quality, total water use, and water-use efficiency at Bushland, Tex., in 1977, 1978, and 1979.

Mulch rate	1977 water level†				1978 water level				1979 water level				Average (1977–1979) water level			
	High	Medium	Low	Avg	High	Medium	Low	Avg	High	Medium	Low	Avg	High	Medium	Low	Avg
Metric tons/ha	Grain-bearing panicles, 1,000's/ha															
0	219 c‡	270 ab	63 f§	184 b¶	135	123	80	113 a	138	143	123	135 a	164#	179	89	144#
2	249 bc	290 a	97 ef	212 a	125	128	108	119 a	138	135	135	136 a	171	184	112	156
4	219 c	293 a	117 de	210 a	128	118	103	116 a	145	143	120	136 a	164	184	113	154
8	233 bc	270 ab	150 d	218 a	120	125	88	111 a	125	140	120	128 a	159	178	119	152
Avg	230 b¶	281 a	107 c		127 a	124 a	94 b		137 a	140 a	125 b		165#	181	108	
	Grain yield, metric tons/ha															
0	2.68	2.74	0.48	1.97 b	2.15	1.93	0.78	1.62 a	2.59	2.42	1.24	2.08 b	2.47	2.36	0.83	1.89
2	3.16	3.09	0.54	2.26 a	1.98	1.86	1.09	1.64 a	2.72	2.77	1.42	2.30 ab	2.62	2.57	1.02	2.07
4	2.93	3.08	0.56	2.19 a	2.06	1.85	1.25	1.72 a	2.99	2.69	1.51	2.40 a	2.66	2.54	1.11	2.10
8	3.07	2.78	0.73	2.19 a	2.20	2.14	0.87	1.74 a	2.79	3.14	1.46	2.46 a	2.69	2.69	1.02	2.13
Avg	2.96 a	2.92 a	0.58 b		2.10 a	1.95 a	1.00 b		2.77 a	2.76 a	1.41 b		2.61	2.54	1.00	
	Forage yield, metric tons/ha															
0	3.5 a	3.2 a	1.4 c	2.7 c	2.2	2.2	2.3	2.2 b	3.4	3.1	2.6	3.0 a	3.0	2.8	2.1	2.6
2	3.8 a	3.2 a	2.3 b	3.1 b	2.1	2.3	2.6	2.3 b	2.8	2.9	2.7	2.8 a	2.9	2.8	2.5	2.7
4	3.4 a	3.7 a	3.2 a	3.4 ab	2.3	2.1	2.5	2.3 b	3.5	3.8	2.2	3.2 a	3.1	3.2	2.6	3.0
8	3.6 a	3.5 a	3.3 a	3.5 a	2.5	2.7	2.8	2.7 a	3.6	3.2	3.0	3.3 a	3.2	3.1	3.0	3.1
Avg	3.6 a	3.4 a	2.6 b		2.3 a	2.3 a	2.6 a		3.3 a	3.3 a	2.6 b		3.1	3.0	2.6	
	Grain test weight, g/liter															
0	821	813	792	809 a	729	741	738	736 a	700	711	736	716 a	750	755	755	753
2	820	810	792	807 a	736	729	722	729 a	716	713	729	719 a	757	751	748	752
4	799	811	789	800 a	740	735	731	735 a	705	704	717	709 a	748	750	746	748
8	810	807	785	801 a	736	736	708	727 a	708	718	709	712 a	751	754	734	746
Avg	813 a	810 a	790 b		735 a	735 a	725 a		707 c	712 b	723 a		752	753	746	
	Grain weight, mg/grain															
0	23.9	20.2	29.2	24.4 a	18.0	18.0	20.8	18.9 a	15.3 bcd	15.0 bcd	16.8 a	15.7 a	19.1	17.7	22.3	19.7
2	25.5	22.6	26.0	24.7 a	18.3	16.8	19.5	18.2 a	15.5 abc	14.3 cde	16.3 ab	15.4 ab	19.8	17.9	20.6	19.4
4	25.7	23.0	25.7	24.8 a	17.8	18.3	20.0	18.7 a	15.5 abc	15.0 bcd	14.0 de	14.8 bc	19.7	18.8	19.9	19.5
8	25.8	24.0	28.1	26.0 a	18.8	18.8	19.0	18.9 a	15.3 bcd	14.8 cd	13.3 e	14.5 c	20.0	19.2	20.1	19.8
Avg	25.2 a	22.5 b	27.3 a		18.2 b	18.0 b	19.8 a		15.4 a	14.8 a	15.1 a		19.7	18.4	20.7	
	Total water use,†† cm															
0	34.3	33.2	23.1	30.6	28.6	27.9	30.1	28.8	33.0	31.9	24.8	29.9	32.0	31.0	26.0	29.6
2	35.1	33.0	23.4	30.9	27.9	27.5	26.7	27.4	31.6	32.1	25.6	29.8	31.5	30.9	25.3	29.2
4	35.8	33.1	20.1	30.0	28.6	27.0	24.1	26.6	31.8	32.1	25.7	29.9	32.1	30.8	23.3	28.7
8	32.8	34.0	17.4	28.4	26.8	26.4	22.0	25.1	33.0	30.5	26.5	30.0	30.9	30.3	22.0	27.7
Avg	34.9	33.7	21.3		28.0	27.2	26.0		32.4	31.7	25.7		31.6	30.7	24.1	
	Water-use efficiency,‡‡ kg/ha-cm (grain)															
0	78	83	21	61	75	69	26	57	79	76	50	68	77	76	32	62
2	90	94	23	69	71	68	41	60	86	86	55	76	82	83	40	68
4	82	93	28	68	72	69	52	64	94	84	59	79	83	82	46	70
8	94	82	42	73	82	81	39	67	85	103	55	81	88	89	45	74
Avg	86	88	29		75	72	40		86	87	55		83	83	41	

† High, medium, and low refer to initial soil water levels established by irrigating twice, irrigating once, or not irrigating, respectively, the areas on which the mulch treatment plots were established.

‡ Row and column values for a given factor and year that are followed by the same letter or letters are not significantly different at the 5% level (Duncan Multiple Range Test). When no letters are shown, the interaction was not significant.

§ The plant population was low in 1977 on low water level treatment plots because of poor germination.

¶ Average row or column values within a group followed by the same letter or letters are not significantly different at the 5% level (Duncan Multiple Range Test).

The average data for 1977 to 1979 were not analyzed statistically.

†† Includes net soil water changes and total rainfall from planting to harvest. Rainfall was 27.8, 24.4, and 18.9 cm in 1977, 1978, and 1979, respectively.

‡‡ Based on grain yield and total water use.

trends seemed related to test weights, but the test weight differences for these treatments were not statistically significant. In 1977 and 1978, grain weights averaged highest and lowest with the low and medium water level treatments, respectively. Some of the differences were statistically significant. Probably the lower number of grain-producing panicles with the low water level treatment than with other treatments in 1977 and 1978 resulted in the development of larger and, therefore, heavier grain. In 1979, however, this trend was not apparent, even though the low water level treatment resulted in the lowest number of panicles.

Soil Water Content Changes

Figure 2 ABC shows available soil water contents after seedling emergence, during the growing season, and at harvest. The net changes in soil water to the 1.8-m depth between the initial and final measurements are shown by numbers on the figures. Soil water changes at the 1.2- to 1.8-m depth were negligible in most cases.

In 1977, the lowest water content was measured on 28 July (Fig. 2A). Above-average August rainfall resulted in higher water contents in the surface increment than at the initial measurement and water contents near the initial values at the 0.6-m depth in the high and medium water level treatment plots on 25 August. Water content tended to increase with increasing mulch rates, and plants extracted most of this water by harvest time. In low water level treatment plots, August rainfall had minor effect on water content in the 0-mulch plots but increased the water content to greater depths as mulch rates increased. Because of the low plant population in these plots, soil water use after the August rainfall was slight, and some of the water moved to the 1.8-m depth. Soil water contents at harvest were higher than at seedling emergence in most cases in the low water level treatment plots, with the net gain increasing with increasing mulch rates.

In 1978, the lowest water contents were measured on 15 September (Fig. 2B). The record rainfall on 19 and 20 September caused soil water contents to equal or exceed the initial values to the 0.6-m depth in most cases. Increasing mulch rates resulted in increasing gains in soil water content. Only a small amount of the water stored from the rainstorm was extracted by plants by harvest time; therefore, water contents at harvest were similar to those at the initial measurement.

Water contents decreased with time in 1979 with the lowest water contents occurring at harvest (12 Oct.) (Fig. 2C). The decrease generally was most rapid in the no-mulch plots and was increasingly slower as mulch rates increased.

Total Water Use and Water-Use Efficiency

Total water-use values (Table 1) are based on net soil water changes (Fig. 2ABC) and total precipitation between planting and harvest. Although some rainwater undoubtedly ran off, runoff was not measured, and no correction was made for runoff. With the high and medium water level treatments, mulch rates had minor effect on total water use, except that the 8 metric ton/ha mulch treatment resulted in less water use than the other treatments in four out of six cases. With the low water level treatment, total water use usually decreased with increasing mulch rates in 1977 and 1978 and increased with increasing mulch rates in 1979. Decreasing water use with increasing mulch rates in the low water level treatment plots in 1977 and 1978 reflect the influence of mulches on accumulation of water from the late season rainfall (Fig. 2AB).

Water-use efficiency was based on grain yields and total water use. The values averaged 83, 83, and 41 kg/ha-cm with the high, medium, and low water level treatments, respectively (Table 1). Mulch rates had no consistent effect on water-use efficiency, but water-use efficiency increased as mulch rates increased in 1977 and 1978 with the low water level treatment and generally increased as mulch rates increased in 1979 with the medium water level treatment. Consequently, water-use efficiency values averaged over water level treatments were lowest with no-mulch and highest with 8 metric tons/ha of mulch each year. For all years, the values were 62, 68, 70, and 74 kg/ha-cm with 0, 2, 4, and 8 metric tons/ha of mulch, respectively.

GENERAL DISCUSSION

Under the rainfall conditions during this 3-year study, a straw mulch on the surface of Pullman clay loam during the growing season had relatively little, although sometimes significant, effect on grain sorghum growth, yield, grain quality, water use, and water-use efficiency. Soil water content at planting generally had a greater effect than mulch rate. The growing seasons of 1977 and 1978 had periods of above- and below-average rainfall. The soil was rather uniformly wetted, regardless of mulch rate, during periods of above-average rainfall; evaporation during subsequent dry periods was little affected by mulch rates because plant canopies were well developed by the time the rainfall occurred. In 1979, rainfall was more frequent and near average in July and August, and soil water depletion was slower with the higher mulch rates. Negligible rainfall in September, however, minimized the potential yield advantage that plants in the high mulch rate plots may have had earlier in the season. Although yields were not greatly influenced by mulch treatments, water-use efficiency increased or tended to increase as mulch rates increased. The 3-year average values were 62 and 74 for the 0 and 8 ton/ha mulch treatments, respectively, a 19% advantage for the high mulch treatment.

The results of this study substantiate the contention (Unger, 1978) that the presence of a surface mulch during the growing season of grain sorghum beneficially affects water-use efficiency. However, the effect was not as large as anticipated. For all data, linear regression analysis showed that yields increased 127 kg/ha for each centimeter of available water in soil to a 1.2-m depth at planting ($y = 31.9 + 126.8x$, $r = 0.506$). When data were deleted for the high and medium water level treatments in 1977, which as a group did not fit the pattern for the other data when plotted (not shown), the relationship showed that yields increased 190 kg/ha for each centimeter increase in water at planting ($y = -1238.4 + 190.3x$, $r = 0.908$).

The value for all data is below the average of 238 obtained by Unger (1978) when the mulch was in place during fallow and the sorghum growing season and even below the value of 170 obtained by Jones and Hauser (1975) when stubble mulch tillage was used. Using the selected data resulted in a value slightly above that of Jones and Hauser (1975).

The value of a mulch for increasing soil water contents, especially during noncropped periods, has often been reported and was demonstrated again in this study in 1977 for the low water level treatments. Because of a low plant population, water extraction was low, and soil water contents increased with increasing mulch rates due to rainfall in August (Fig. 2A). We therefore, concluded that a major effect of a mulch on water conservation and crop production is enhancement of water storage in soil before crop planting. Plant canopy development largely overshadows the beneficial effect that a growing season mulch may have on efficient use of water in crop production in the Southern Great Plains. Where water conservation is of major importance, these conclusions suggest that a mulch should be maintained on soil between crops to enhance water storage, which increases crop yields (Unger, 1978; Unger and Wiese, 1979). At planting, the mulch could be managed to avoid planting difficulties, lower temperatures, phytotoxicities, and so forth, that have occurred with mulches in some cases. However, maintenance of crop residues on the surface during the growing season should be considered for controlling erosion.

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